Application Programming With SQL

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Reference:
A First Course in Database Systems, 3rd edition, Chapter 9

SQL in Real Programs

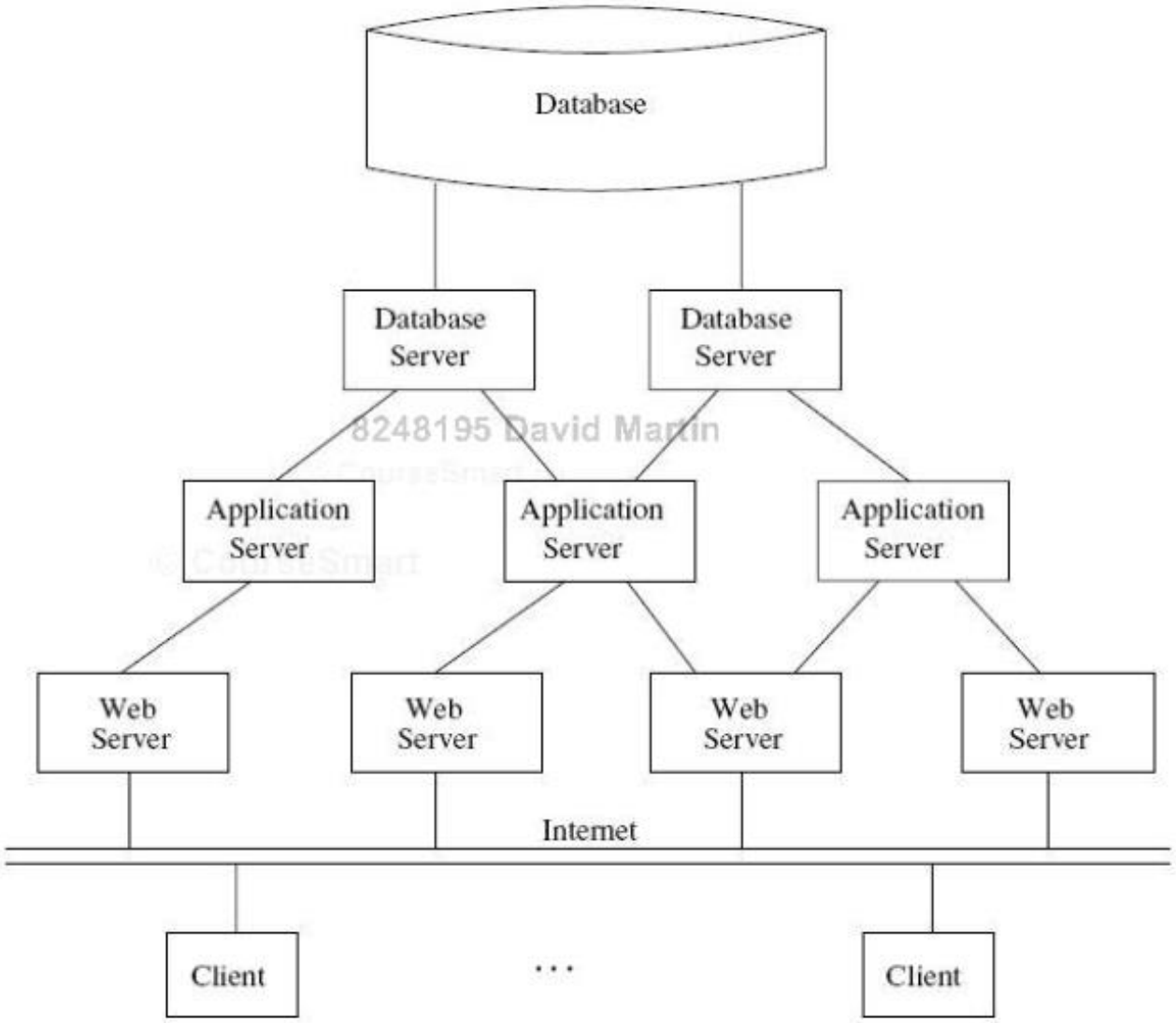
- We have seen only how SQL is used at the generic query interface --- an environment where we sit at a terminal and ask queries of a database.
- Reality is almost always different: conventional programs interacting with SQL.
- Why?

Three-Tier Architecture

- A common environment for using a database has three tiers of processors:
  1. *Web servers* --- talk to the user.
  2. *Application servers* --- execute the "business logic".
  3. *Database servers* --- get what the app servers need from the database.

See Chapter 9, Figure 1

3-Tier Architecture



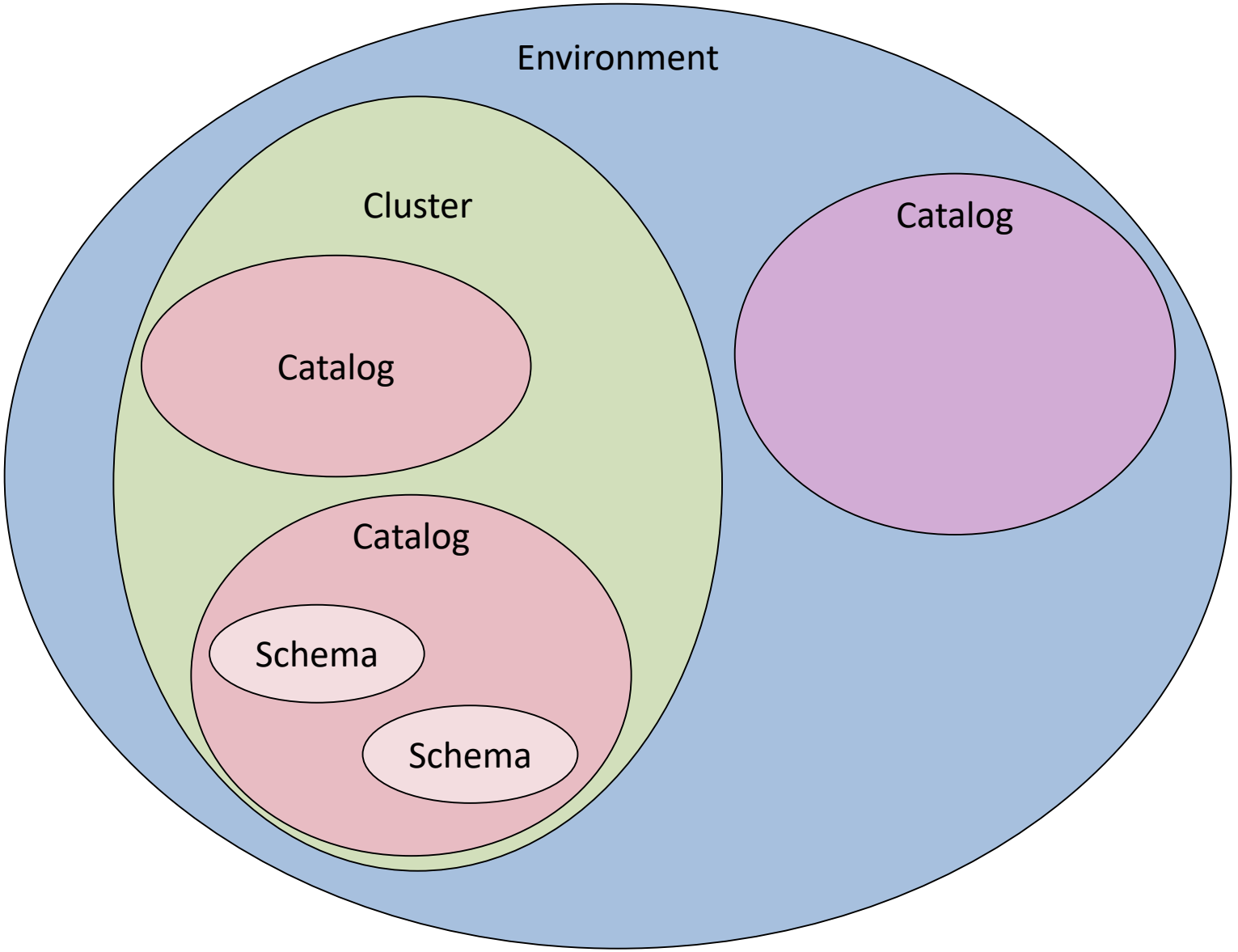
Example: Amazon

- Database tier holds the information about products, customers, etc.
- Application tier ("business logic") includes things like "What do I do after someone clicks 'checkout'?"
  - Answer: Show the "How will you pay for this?" screen.
- Web-server tier handles preparation and display of Web pages

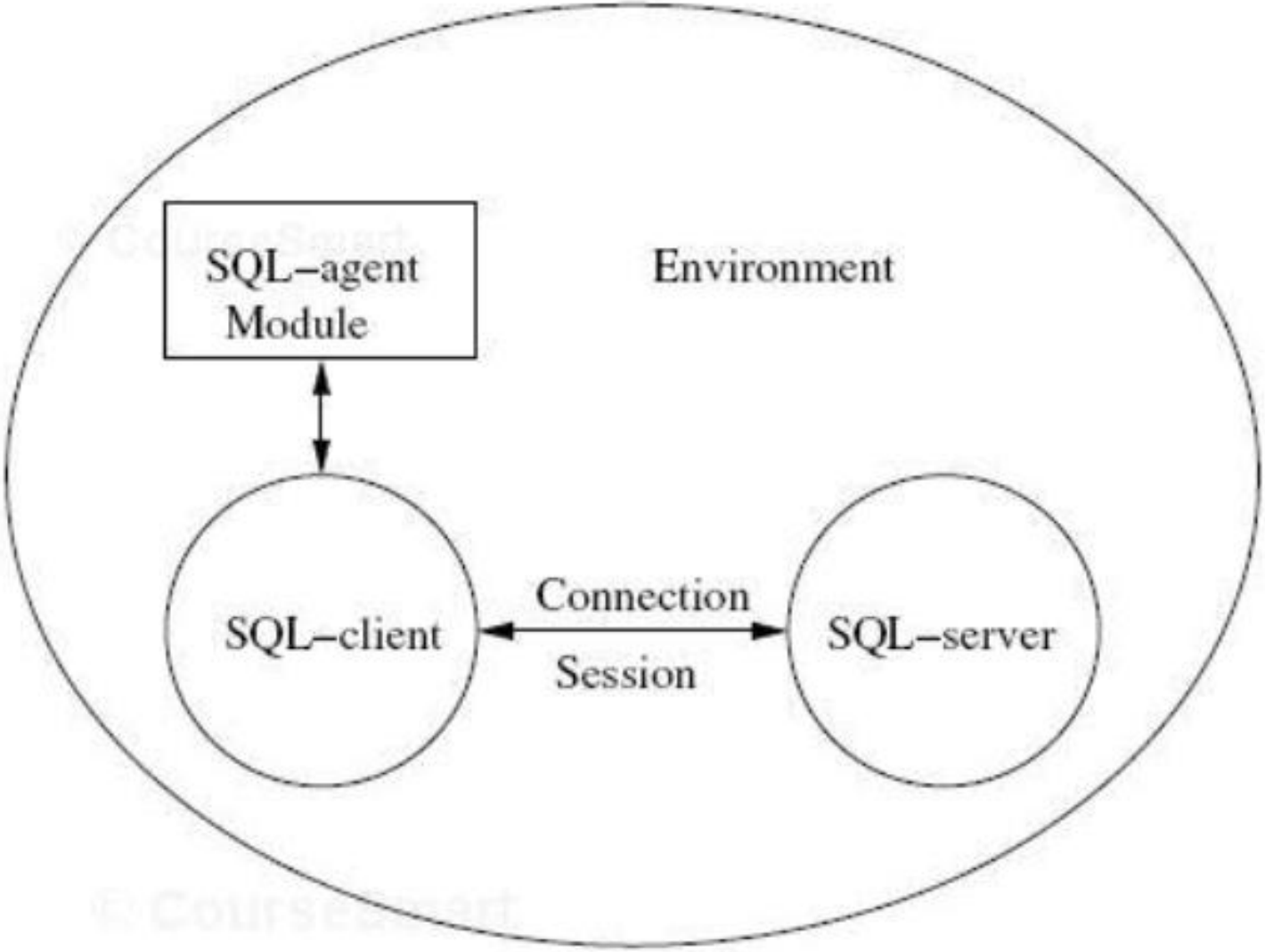
Environments, Clients, Connections

- SQL defines a specific meaning of *environment,* which includes clusters and catalogs as organizational elements.
  - A *cluster* defines the maximum scope of a DB operation
  - A *catalog* contains a number of uniquely named schemas
  - ➔ See next slide
- A SQL environment also includes (normally many of) these:
  - *Client* – a program that queries the database
    - In the 3-tier architecture, the application programs (middle tier) are the clients
  - *Connection* – a communications channels between the database and a client
    - Databases support some number of simultaneous *connections*, so clients can connect, submit statements (queries or modifications), and then disconnect.
  - ➔ See Chapter 9, Figure 4
- A *session* is the sequence of statements and responses that is exchanged over a connection.

Schema and Organizational Elements of the SQL Environment



Client / Server Interactions



Declaring a Schema

- You can create an entire schema all at once

```
CREATE SCHEMA MovieSchema
  CREATE TABLE Movies ( … )
  ….
  CREATE VIEW MovieProd AS …
  ….
  CREATE ...other types of things... ;
```

  and make it belong to a catalog (syntax not shown)
- You can set a current catalog and/or schema

```
SET CATALOG MovieCatalog ;
SET SCHEMA MovieSchema ;
```

- In the absence of a current catalog and schema, you may need to use a table's fully qualified name

```
MovieCatalog.MovieSchema.Movies
```

Approaches to Programming With SQL

1. Code in a specialized language is stored in the database itself (e.g., **stored procedure** languages such as PSM and PL/SQL).
2. SQL statements are **embedded in a host language** (e.g., C).
   - Approach 2 out of scope for CMPS 182
3. **Connection tools/libraries** are used to allow a **conventional language** to access a database (e.g., CLI, JDBC).

Approach 1: Stored Procedures

- PSM, or "*persistent stored modules*," allows us to store procedures as database schema elements.
- PSM = a mixture of conventional statements (if, while, etc.) and SQL.
- Lets us do things we cannot do in SQL alone.

The Procedure

CREATE PROCEDURE JoeMenu (

```
IN    b    CHAR(20),
IN p  REAL
```

Parameters are both read-only, not changed

)

```
INSERT INTO Sells
VALUES('Joe''s Bar', b, p);
```

The body --- a single insertion

Basic PSM Form

CREATE PROCEDURE <name> (

<parameter list>)

<optional local declarations>

<body>;

- Function alternative:

CREATE FUNCTION <name> (

<parameter list>) RETURNS <type>

Parameters in PSM

- Unlike the usual name-type pairs in languages like C, PSM uses mode-name-type triples, where the *mode* can be:
  - IN = procedure uses value, does not change value.
  - OUT = procedure changes, does not use.
  - INOUT = both.
- Function parameters must be of mode IN. Functions returns a value, but must have no side-effects.

Example: Stored Procedure

- Let's write a procedure that takes two arguments *b* and *p*, and adds a tuple to Sells(bar, beer, price) that has bar = 'Joe''s Bar', beer = *b*, and price = *p*.
  - Used by Joe to add to his menu more easily.

The Procedure

CREATE PROCEDURE JoeMenu (

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```
INSERT INTO Sells
VALUES('Joe''s Bar', b, p);
```

The body --- a single insertion

Invoking Procedures

- Use SQL/PSM statement CALL, with the name of the desired procedure and arguments.
- Example:

```
CALL JoeMenu('Moosedrool', 5.00);
```

- Functions may be used in SQL expressions wherever a value of their return type is appropriate.

Example: IF (continued)

```
CREATE FUNCTION Rate (IN b CHAR(20) )
        RETURNS CHAR(10)
        DECLARE cust INTEGER;
    BEGIN
        SET cust = (SELECT COUNT(*) FROM Frequents
                    WHERE bar = b);
        IF cust < 100 THEN RETURN 'unpopular'
        ELSEIF cust < 200 THEN RETURN 'average'
        ELSE RETURN 'popular'
        END IF;
    END;
```

Number of customers of bar b

Nested IF statement

Return occurs here, not at one of the RETURN statements

Kinds of PSM statements – (1)

- RETURN <expression> sets the return value of a function.
  - Unlike C, etc., RETURN *does not* terminate function execution.
- DECLARE <name> <type> used to declare local variables.
- BEGIN . . . END for groups of statements.
  - Separate statements by semicolons.

Kinds of PSM Statements – (2)

- Assignment statements:

  SET <variable> = <expression>;

  - Example: `SET b = 'Bud';`

- Statement labels: give a statement a label by prefixing a name and a colon.

IF Statements

- Simplest form:
  IF <condition> THEN
  <statements(s)>
  END IF;

- Add ELSE <statement(s)> if desired, as
  IF . . . THEN . . . ELSE . . . END IF;

- Add additional cases by ELSEIF <statements(s)>:
  IF … THEN … ELSEIF … THEN … ELSEIF …
  THEN … ELSE … END IF;

Example: IF

- Let's rate bars by how many customers they have, based on Frequents(drinker,bar).
  - <100 customers: 'unpopular'.
  - 100-199 customers: 'average'.
  - >= 200 customers: 'popular'.
- Function Rate(b) rates bar b.

Example: IF (continued)

```
CREATE FUNCTION Rate (IN b CHAR(20) )
        RETURNS CHAR(10)
        DECLARE cust INTEGER;
    BEGIN
        SET cust = (SELECT COUNT(*) FROM Frequents
                    WHERE bar = b);
        IF cust < 100 THEN RETURN 'unpopular'
        ELSEIF cust < 200 THEN RETURN 'average'
        ELSE RETURN 'popular'
        END IF;
    END;
```

Number of customers of bar b

Nested IF statement

Return occurs here, not at one of the RETURN statements

Loops

- Basic form:

  <loop name>: LOOP <statements>
  END LOOP;

- Exit from a loop by:

  LEAVE <loop name>

Example: Exiting a Loop

```
loop1: LOOP
        . . .
        LEAVE loop1;
        . . .
END LOOP;
```

If this statement is executed . . .

Control winds up here

Other Loop Forms

- WHILE <condition>
  DO <statements>
  END WHILE;

- REPEAT <statements>
  UNTIL <condition>
  END REPEAT;

Queries

- General SELECT-FROM-WHERE queries are *not* permitted in PSM.
- There are three ways to get the effect of a query:
  1. Queries producing one value can be the expression in an assignment.
  2. Single-row SELECT . . . INTO …
  3. Cursors

Example: Assignment/Query

- Using local variable *p* and Sells(bar, beer, price), we can get the price Joe charges for Bud by:

```
SET p = (SELECT price FROM Sells
 WHERE bar = 'Joe''s Bar'
   AND beer = 'Bud');
```

SELECT . . . INTO …

- Another way to get the value of a query that returns one tuple is by placing INTO <variable> after the SELECT clause.
- Example:

```
SELECT price INTO p
FROM Sells
WHERE bar = 'Joe''s Bar'
  AND beer = 'Bud';
```

Cursors

- A *cursor* is essentially a tuple-variable that ranges over all tuples in the result of some query.

- Declare a cursor *c* by:

  DECLARE c CURSOR FOR <query>;

The Needed Declarations

```
CREATE PROCEDURE JoeGouge( )
    DECLARE theBeer CHAR(20);
    DECLARE thePrice REAL;
    DECLARE NotFound CONDITION FOR
     SQLSTATE '02000';
    DECLARE c CURSOR FOR
     (SELECT beer, price FROM Sells
      WHERE bar = 'Joe''s Bar');
```

Used to hold beer-price pairs when fetching through cursor c

Returns Joe's menu

The Procedure Body

```
BEGIN
    OPEN c;
    menuLoop: LOOP
        FETCH c INTO theBeer, thePrice;
        IF NotFound THEN LEAVE menuLoop END IF;
        IF thePrice < 3.00 THEN
            UPDATE Sells SET price = thePrice + 1.00
            WHERE bar = 'Joe''s Bar' AND beer = theBeer;
        END IF;
    END LOOP;
    CLOSE c;
END;
```

Check if the recent FETCH failed to get a tuple

If Joe charges less than $3 for the beer, raise its price at Joe's Bar by $1.

Opening and Closing Cursors

- To use cursor *c*, we must issue the command:

  OPEN c;

  - The query of *c* is evaluated, and *c* is set to point to the first tuple of the result.

- When finished with *c*, issue command:

  CLOSE c;

Fetching Tuples From a Cursor

- To get the next tuple from cursor c, issue command:

  FETCH FROM c INTO x1, x2,…,x*n* ;

- The *x*'s are a list of variables, one for each component of the tuples referred to by *c*.

- c is moved automatically to the next tuple.

Breaking Cursor Loops – (1)

- The usual way to use a cursor is to create a loop with a FETCH statement, and do something with each tuple fetched.

- A tricky point is how we get out of the loop when the cursor has no more tuples to deliver.

Breaking Cursor Loops – (2)

- Each SQL operation returns a *status*, which is a 5-digit character string.
  - For example:
    - '00000' means "Everything OK,"
    - '02000' means "Failed to find a tuple."
- In PSM, we can get the value of the status in a variable called SQLSTATE.

Breaking Cursor Loops – (3)

- We may declare a *condition*, which is a boolean variable that is true if and only if SQLSTATE has a particular value.

- Example: We can declare condition `NotFound` to represent 02000 by:

```
DECLARE NotFound CONDITION FOR
    SQLSTATE '02000';
```

Breaking Cursor Loops – (4)

- The structure of a cursor loop is thus:

```
cursorLoop: LOOP
  …
  FETCH c INTO … ;
  IF NotFound THEN LEAVE cursorLoop;
  END IF;
  …
END LOOP;
```

Example: Cursor

- Let's write a procedure that examines Sells(bar, beer, price), and raises by one dollar the price of all beers at Joe's Bar that are under three dollars.
  - Yes, we could write this as a simple UPDATE, but the details are instructive anyway.

The Needed Declarations

```
CREATE PROCEDURE JoeGouge( )
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            UPDATE Sells SET price = thePrice + 1.00
            WHERE bar = 'Joe''s Bar' AND beer = theBeer;
        END IF;
    END LOOP;
    CLOSE c;
END;
```

Check if the recent FETCH failed to get a tuple

If Joe charges less than $3 for the beer, raise its price at Joe's Bar by $1.

PL/SQL

- Oracle uses a variant of SQL/PSM which it calls PL/SQL.
- PL/SQL not only allows you to create and store procedures or functions, but it can be run from the *generic query interface* (sqlplus), like any SQL statement.
- Triggers are a part of PL/SQL.

Approach 3: Host Language/SQL Interfaces via Libraries

- The third approach to connecting databases to conventional languages is to use library calls.
  1. C + CLI
  2. Java + JDBC
  3. PHP + PEAR/DB

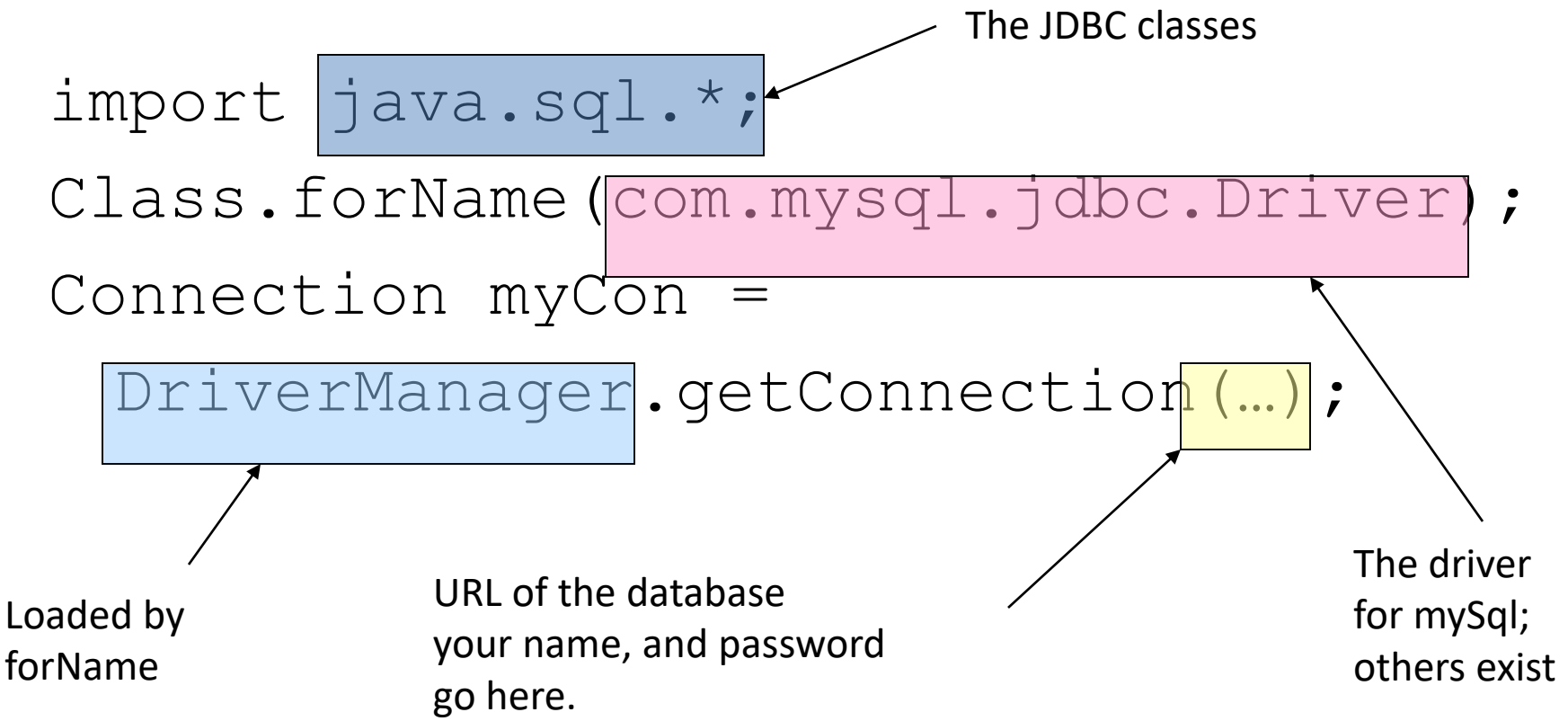
SQL/CLI

- Instead of using a preprocessor (as in embedded SQL), we can use a library of functions.
  - The library for C is called SQL/CLI = "*Call-Level Interface*."

JDBC

- *Java Database Connectivity* (JDBC) is a library similar to SQL/CLI, but with Java as the host language.
- Like CLI, but with a few differences.

Making a Connection



Statements

- JDBC provides two classes:
  1. *Statement* is an object that can accept a string that is a SQL statement and can execute such a string.
  2. *PreparedStatement* is an object that has an associated SQL statement ready to execute.

Creating Statements

- The Connection class has methods to create Statements and PreparedStatements.

```
Statement stat1 = myCon.createStatement();
PreparedStatement stat2 =
    myCon.createStatement(
     ”SELECT beer, price FROM Sells ” +
     ”WHERE bar = ’Joe’ ’s Bar’ ”
    );
```

createStatement with no argument returns a Statement; with one argument it returns a PreparedStatement.

Executing SQL Statements

- JDBC distinguishes queries from modifications, which it calls "updates."
- Statement and PreparedStatement each have methods executeQuery and executeUpdate.
  - For Statements: one argument: the query or modification to be executed.
  - For PreparedStatements: no argument.

Example: Update

- stat1 is a Statement.
- We can use it to insert a tuple:

```
stat1.executeUpdate(
  ”INSERT INTO Sells ” +
  ”VALUES(’Brass Rail’,’Bud’,3.00)”
);
```

Example: Query

- stat2 is a PreparedStatement holding the query ”SELECT beer, price FROM Sells WHERE bar = ’Joe’’s Bar’ ”.

- executeQuery returns an object of class ResultSet; we’ll examine that soon.

- The query:

```
ResultSet menu = stat2.executeQuery();
```

Accessing the ResultSet

- An object of type ResultSet is a lot like a cursor.
- Method next() advances the "cursor" to the next tuple.
  - The first time next() is applied, it gets the first tuple.
  - If there are no more tuples, next() returns the value false.

Accessing Components of Tuples

- When a ResultSet refers to a tuple, we can get the components of that tuple by applying certain methods to the ResultSet.
- Method get*X* (*i*), where *X* is some type, and *i* is the component number, returns the value of that component.
  - The value must have type *X*.

Example: Accessing Components

- Menu = ResultSet for query "SELECT beer, price FROM Sells WHERE bar = 'Joe' 's Bar' ".

- Access beer and price from each tuple by:

```
while ( Menu.next() ) {
  theBeer = Menu.getString(1);
  thePrice = Menu.getFloat(2);
   /*something with theBeer and
  thePrice*/
}
```

Approach 2: Embedded SQL

- Key idea: A preprocessor turns SQL statements into procedure calls that fit with the surrounding host-language code.
- All embedded SQL statements begin with EXEC SQL, so the preprocessor can find them easily.

- Approach 2 (all the remaining slides in this set) is out of scope for CMPS 182

This slide and all others on Embedded SQL are out-of-scope for CMPS 182

Shared Variables

- To connect SQL and the host-language program, the two parts must share some variables.
- Declarations of shared variables are bracketed by:

Always needed

EXEC SQL BEGIN DECLARE SECTION;

<host-language declarations>

EXEC SQL END DECLARE SECTION;

This slide and all others on Embedded SQL are out-of-scope for CMPS 182

Use of Shared Variables

- In SQL, the shared variables must be preceded by a colon.
  - They may be used as if they were constants provided by the host-language program.
  - They may get values from SQL statements and pass those values to the host-language program.
- In the host language, shared variables behave like any other variable.

Example: Looking Up Prices

- We'll use C with embedded SQL to sketch the important parts of a function that obtains a beer and a bar, and looks up the price of that beer at that bar.
- Assumes database has the Sells(bar, beer, price) relation.

This slide and all others on Embedded SQL are out-of-scope for CMPS 182

Example: C with SQL

```
EXEC SQL BEGIN DECLARE SECTION;
    char theBar[21], theBeer[21];
    float thePrice;
EXEC SQL END DECLARE SECTION;
  /* obtain values for theBar and theBeer */
EXEC SQL SELECT price INTO :thePrice
    FROM Sells
    WHERE bar = :theBar AND beer = :theBeer;
  /* do something with thePrice */
```

Note 21-char arrays needed for 20 chars + endmarker

SELECT-INTO as in PSM

This slide and all others on Embedded SQL are out-of-scope for CMPS 182

Embedded Queries

- Embedded SQL has the same limitations as PSM regarding queries:
  - SELECT-INTO for a query guaranteed to produce a single tuple.
  - Otherwise, you have to use a cursor.
    - Small syntactic differences, but the key ideas are the same.

This slide and all others on Embedded SQL are out-of-scope for CMPS 182

Cursor Statements

- Declare a cursor *c* with:

EXEC SQL DECLARE *c* CURSOR FOR <query>;

- Open and close cursor c with:

EXEC SQL OPEN CURSOR c;

EXEC SQL CLOSE CURSOR c;

- Fetch from *c* by:

EXEC SQL FETCH c INTO <variable(s)>;

  - You can write a macro NOT_FOUND that is true if and only if the FETCH fails to find a tuple.

This slide and all others on Embedded SQL are out-of-scope for CMPS 182

Example: Print Joe's Menu

- Let's write C + SQL to print Joe's menu – the list of beer-price pairs that we find in Sells(bar, beer, price) with bar = Joe's Bar.

- A cursor will visit each Sells tuple that has bar = Joe's Bar.

Example: Declarations

```
EXEC SQL BEGIN DECLARE SECTION;
    char theBeer[21]; float thePrice;
EXEC SQL END DECLARE SECTION;
EXEC SQL DECLARE c CURSOR FOR
    SELECT beer, price FROM Sells
    WHERE bar = 'Joe''s Bar';
```

The cursor declaration goes outside the declare-section

Example: Executable Part

```
EXEC SQL OPEN CURSOR c;
while(1) {
    EXEC SQL FETCH c
        INTO :theBeer, :thePrice;
    if (NOT_FOUND) break;
    /* format and print theBeer and thePrice */
}
EXEC SQL CLOSE CURSOR c;
```

The C style of breaking loops

This slide and all others on Embedded SQL are out-of-scope for CMPS 182

Need for Dynamic SQL

- Most applications use specific queries and modification statements to interact with the database.
  - The DBMS compiles EXEC SQL … statements into specific procedure calls and produces an ordinary host-language program that uses a library.

This slide and all others on Embedded SQL are out-of-scope for CMPS 182

Dynamic SQL

- Preparing a query:

  EXEC SQL PREPARE <query-name>

  FROM <text of the query>;

- Executing a query:

  EXEC SQL EXECUTE <query-name>;

- "Prepare" means optimize query.
- Prepare once, Execute many times.

Example: A Generic Interface

```
EXEC SQL BEGIN DECLARE SECTION;
   char query[MAX_LENGTH];
EXEC SQL END DECLARE SECTION;
while(1) {
   /* issue SQL> prompt */
   /* read user's query into array query */
   EXEC SQL PREPARE q FROM :query;
   EXEC SQL EXECUTE q;
}
```

q is an SQL "query variable" representing the optimized form of whatever statement is typed into :query

This slide and all others on Embedded SQL are out-of-scope for CMPS 182

Execute-Immediate

- If we are only going to execute the query once, we can combine the PREPARE and EXECUTE steps into one.

- Use:

    EXEC SQL EXECUTE IMMEDIATE <text>;

This slide and all others on Embedded SQL are out-of-scope for CMPS 182

Example: Generic Interface Again

```
EXEC SQL BEGIN DECLARE SECTION;
  char query[MAX_LENGTH];
EXEC SQL END DECLARE SECTION;

while(1) {
  /* issue SQL> prompt */
  /* read user's query into array query
  */
  EXEC SQL EXECUTE IMMEDIATE :query;
}
```